U. S. Department of the Interior
U. S. Geological Survey

CHESAPEAKE BAY HABITAT CRITERIA SCORES AND THE DISTRIBUTION OF SUBMERSED AQUATIC VEGETATION IN THE TIDAL POTOMAC RIVER AND POTOMAC ESTUARY, 1983-1997

Open-File Report 99-219

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
1999	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Chesapeake Bay Habitat Criteria Scores and the Distribution of Submersed Aquatic Vegetation in The Tidal Potomac River and Potomac Estuary, 1983-1997	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Department of the Interior 1849 C Street, NW Washington, DC 20240**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**40**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

CHESAPEAKE BAY HABITAT CRITERIA SCORES AND THE DISTRIBUTION OF SUBMERSED AQUATIC VEGETATION IN THE TIDAL POTOMAC RIVER AND POTOMAC ESTUARY, 1983-1997

By Jurate M. Landwehr, Justin T. Reel, Nancy B. Rybicki, Henry A. Ruhl and Virginia Carter

U.S. Geological Survey

Open-File Report 99-219

Reston, Virginia

1999

U. S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, *Secretary*

U. S. GEOLOGICAL SURVEY
Charles G. Groat, *Director*

For additional information write to:

Chief, Regional Hydrologic
Processes Project
U.S. Geological Survey
MS 431 - National Center
Reston, Virginia 20192 USA

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Federal Center
Denver, Colorado 80225-0286 USA

CONTENTS

ILLUSTRATIONS

TABLES

CHESAPEAKE BAY HABITAT CRITERIA SCORES AND THE DISTRIBUTION OF SUBMERSED AQUATIC VEGETATION IN THE TIDAL POTOMAC RIVER AND POTOMAC ESTUARY, 1983-1997

by

Jurate M. Landwehr, Justin T. Reel, Nancy B. Rybicki,

Henry A. Ruhl, and Virginia Carter

ABSTRACT

The Chesapeake Bay Program has identified habitat requirements for the restoration of submersed aquatic vegetation (SAV) in the Chesapeake Bay estuary and tidal reaches of contributing river systems conditioned on the salinity regime of a specific location. The tidal Potomac River and Potomac Estuary is an important component of the Chesapeake Bay system to which these requirements can be applied. The SAV habitat requirements are formulated as threshold criteria that certain critical water-quality characteristics must satisfy during the SAV growing season. A multivariate scoring system based on these criteria was developed in order to synopsize water quality conditions during the 1983-1997 SAV growing seasons. Chesapeake Bay habitat criteria scores are displayed relative to annual SAV coverage for each Potomac River and Potomac Estuary segment. It is seen that although there is some correspondence in the inter-annual expansion or contraction of SAV coverage and compliance with Chesapeake Bay SAV habitat criteria, individual criteria provide neither necessary nor sufficient conditions to explain inter-annual dynamics of SAV coverage, especially in the Potomac Estuary .

INTRODUCTION

The objective of the U.S. Geological Survey's (USGS) Chesapeake Bay Ecosystem Program is to provide information on ecosystem structure responses to changes in water quality , especially nutrients, and to climate variability. This information is used by the broad community of policy makers, resource managers, scientists, and private citizens working on the environmental restoration of the Chesapeake Bay, including the Chesapeake Bay Program (CBP) – which is coordinated by the U.S. Environmental Protection Agency (EPA). During this century, the ecosystem of the Chesapeake Bay, the Nation's largest estuary, has been adversely affected by the loss of submersed aquatic vegetation (SAV) throughout the system. These primary producers form the base of the food chain and provide critical habitat for many of the living resources of the estuary, such as finfish, shellfish, and waterfowl. Decline in SAV has been attributed primarily to decreased water clarity, in response to increases in nutrient and sediment loads that have accompanied regional population growth.

As part of the USGS mission, USGS scientists are collecting and analyzing data related to current and historical nutrient and sediment loads in the drainage basin of the Chesapeake Bay and determining linkages between water quality and the distribution and abundance of SAV in the Potomac River drainage basin. In the tidal Potomac River, since the early 1980's, there has been both a dramatic resurgence as well as a retreat of SAV. The resurgence has been attributed primarily to improved waste-water treatment leading to improved water-column clarity over this time period. (Carter and Rybicki, 1986.) At the same time, there has been a minimal but consistently positive trend in the reemergence of SAV in the Potomac Estuary . This report provides information about the variations in the areal coverage of SAV in the tidal Potomac River and Potomac Estuary in relation to variations in water-quality as defined by CBP criteria for the period 1983 through 1997.

TIDAL POTOMAC RIVER AND POTOMAC ESTUARY SEGMENTATION AND COVERAGE BY SUBMERSED AQUATIC VEGETATION

The tidal Potomac River and Estuary extends 183 km from Little Falls near Chain Bridge in Washington, D.C., down to the river's mouth at the Chesapeake Bay. For its studies, the CBP has divided the Potomac River and Estuary into three segments by salinity regimes -- tidal fresh, oligohaline and mesohaline. Before 1997, the CBP defined these segments as TF2, RET2 and LE2, respectively, but they have since been redefined and renamed POTTF, POTOH, and POTMH, respectively. (Table 1 summarizes the various abbreviations used throughout this report.) In this report, data are reported by the three segments TF2, POTOH, and POTMH, as shown in Figure 1. Differences in realignment between the oligohaline (RET2 versus POTOH) and mesohaline (LE2 versus POTMH) segments were significant. Realignment within the freshwater tidal regime (TF2 versus POTTF) consisted primarily of the exclusion of two creek areas from the TF2. This designation of POTTF impeded historical comparisons, so that TF2, rather than POTTF, was used in this study .

For USGS study purposes, the tidal fresh segment, TF2, has been further subdivided into two segments, an upper tidal fresh (UTR) and lower tidal fresh (LTR) segment. (Carter and Rybicki, 1986; Carter and Rybicki in Batiuk and others, 1992.) Studies have indicated that historical patterns of SAV growth in UTR and LTR segments have been different (Landwehr and others, 1997). With respect to the TF2 versus POTTF designation, the POTTF designation would exclude SAV-contributing areas from Piscataway Creek in the UTR and from Mattowoman Creek in the LTR. The areal coverage of SAV in UTR and in LTR sum to that in the TF2; hence, to facilitate time series comparisons, we have chosen to retain the TF2 segment.

The growing season for SAV in the Potomac River extends from April through October. Using aerial photographs and on-site assessments, the Virginia Institute of Marine Science (Orth and others, 1997; and internet site http://www.vims.edu/bio/sav/) provides estimates of the annual SAV coverage in hectares for each of these CBP

segments. USGS researchers, working with researchers at the Virginia Institute of Marine Science, have further partitioned the TF2 SAV coverage into coverage within the UTR and LTR segments. A summary of SAV coverage by river segment for the period 1983 through 1997 is given in Table 2.

The Maryland Department of Natural Resources (MD DNR) routinely collects water-quality data in the Potomac River and Potomac Estuary at nine locations, including four stations in TF2 with two each in UTR and LTR, two stations in POTOH, and three stations in POTMH, as shown in Figure 1. Because the areas of the salinity regime-based river segments that have been adopted by the CBP are fairly large, we have also considered smaller river segments around each of the nine water-quality monitoring sites. Each river segment consists of the six-kilometer river-length area which encompasses the water-quality site; that is, the segment comprises the three-kilometer river-length areas immediately above and downstream from a water-quality monitoring site. The SAV coverage for each of these monitoring station segments was determined jointly by workers at the USGS and at the Virginia Institute of Marine Science. SAV coverage in hectares by station segment and year is given in Table 3.

WATER-QUALITY DATA

The MD DNR routinely analyzes water samples for a suite of water-quality parameters. Generally, two samples per month are collected during the SAV growing season (April through October). According to Batiuk and others (1992), five water quality parameters are considered to be particularly relevant for SAV habitat restoration and SAV survival -- Secchi depth (SECCHI), total suspended solids (TSS), chlorophyll-a concentration (CHLA), dissolved inorganic phosphorus (DIP), and dissolved inorganic nitrogen (DIN). We obtained data sets for these five parameters from the MD DNR Sampling Program for April through October for the period 1983 through 1997.

The following quality control procedures were followed in preparing the data for analysis. First, data obtained from the MD DNR was examined for outliers and any

extraordinary values were discussed with MD DNR staff. In a very few cases, numbers were adjusted, but only in accordance with recommendations by MD DNR staff. Second, a small number of measurements were reported to be below the detection limit of the respective analytical procedure. After examination of the distribution of the seasonal data for each respective parameter for any season during which a value below the detection limit was reported, we decided to set those values equal to the detection limit because the seasonal distributions were not markedly affected. Third, in several cases, replicate samples were analyzed and two measurements were reported for the same parameter on the same day at the same time and location. In these cases, the two measurements were averaged and the average was used in the analysis, unless one of the measurements was reported as below the detection limit, in which case only the measurement not below the detection limit was used.

In discussing the data with staff at MD DNR, we discovered that from 1991 forward, analyses for DIP and DIN were run on filtered water samples, whereas prior to 1991, all analyses were performed on unfiltered samples. Unfortunately, no overlap sampling period existed during which both filtered and unfiltered samples were analyzed. Thus, it is possible that our results reflect changes in sampling procedures in addition to variations in river column conditions before and after 1990.

The median seasonal value for the set of measurements for each parameter for each year was computed. For the CBP segments, measurements made at each water-quality monitoring site within the respective segment were pooled and the season median was computed for the entire data set. Median values for the SAV growing season for the pertinent parameters for years 1983 through 1997 are given in Tables 4-8 for the UTR, LTR, TF2, POTOH and POTMH segments, respectively. Median values for the SAV growing season for the five parameters for years 1983 through 1997 for the nine water-quality monitoring station segments are given in Tables 9-17. Again, samples for DIP and DIN were analyzed differently after the 1990 season, and the contents of the tables are qualified by this observation.

CHESAPEAKE BAY HABITAT CRITERIA AND SCORES

The CBP identified salinity-regime based criteria for certain critical water-quality parameters in order to assure the restoration of SAV. These parameters were identified in Table IV-1 (p.27) of the Chesapeake Bay Technical Synthesis Report (Batiuk and others, 1992). A DIP criterion specifically for the tidal Potomac River and Potomac Estuary was given in Table V-10 (page 74) of that same report. These criteria are presented in Table 18, expressed as bounds on the median values of samples collected during the SAV growing season (April-October). Note that the criterion for the light attenuation coefficient is expressed in terms of the more commonly made measurement of Secchi depth (SECCHI) by using the conversion factor assumed for the Chesapeake Bay by the CBP, namely SECCHI=1.45/(light attenuation coefficient); to be conservative, terms are rounded up. Note also that the criterion is equivalent to one expressed as per cent (%) light saturation in reference to a specified depth in the water column, for example, the one-meter restoration goal . The growing season (April-October) medians were calculated for the period 1983 through 1997. These are shown by salinity regime segment in Tables 5-11, and by monitoring station in Tables 12-20.

In order to summarize for management purposes whether or not the criteria have been historically satisfied, the median seasonal sample values for the water quality parameters for the several tidal Potomac River and Estuary segments can be converted into "achievement scores", which are here called "Chesapeake Bay habitat criteria scores". A score is assigned for each water-quality parameter by river segment for each year studied by the steps outlined in 1-3 below.

1. Consider a river segment **r** which is in salinity regime **s** (fresh, oligohaline or mesohaline). For each water-quality parameter **i,** the median value of measurements made for samples taken during the SAV growing season (April-October) in year **t** is represented as median **(i,r,t)**. Table 18 presents the criterion **(i,s**) to which the median in salinity regime s for water quality parameter **i** is compared.

2. For **i** = TSS, CHLA, DIP and DIN, the criteria define an upper bound which the seasonal median should not exceed. The Chesapeake Bay habitat score is computed to be:

Score **(i,r,t)** = 1- [median (**i,r,t**) / criterion (**i,s**)] ;

but

if Score (**i,r,t**) < -1, then set Score **(i,r,t)** = -1.

3. For **i** = SECCHI, the criterion defines a lower bound for the seasonal median. The Chesapeake Bay habitat score is computed as follows.

Score **(i,r,t)** = **[**median (**i,r,t**) / criterion (**i,s**)] – 1 ;

but

if Score (**i,r,t**) > +1, then set Score **(i,r,t)** = +1.

Thus, for each water quality characteristic, the score is bounded; that is,

$-1 \leq$ Score **(i,r,t)** $\leq +1$**.**

When a criterion is satisfied for a particular year, Score **(i,r,t)** $\geq$ 0, but when a criterion is not satisfied during a particular season, Score **(i,r,t)** < 0. If Score **(i,r,t)** = 0, then the criterion has just been met.

Figures 2 through 15 include bar charts to graphically depict the scores for each water quality parameter and river segment derived from the seasonal median values presented in Tables 4 through 17, respectively , and the criteria in Table 18.

CHESAPEAKE BAY HABITAT CRITERIA SCORES AND COVERAGE BY SUBMERSED AQUATIC VEGETATION

SAV coverage given in Tables 2 and 3 is also graphically displayed in Figures 2 through 15; SAV coverage for each of the CBP and USGS segments are shown in Figures 2 through 6, and for each of the water quality monitoring station segments in Figures 7 through 15. Also denoted on these figures is an indication when analytical procedures changed and filtered rather than unfiltered samples were used for analysis.

In the freshwater tidal Potomac River segments UTR, LTR and TF2, SAV coverage predominantly corresponds to fluctuations of the Chesapeake Bay habitat scores: SAV coverage tended to increase between years if the scores were predominantly positive and decrease as scores became negative. In the oligohaline Potomac Estuary segment POTOH, the correspondence is more mixed, possibly confounded by the change in analytical procedures. In the mesohaline Potomac Estuary segment POTMH, there appears to be little correspondence to either the sign or the magnitude of the scores. SAV coverage remains minimal, albeit trending positively, throughout this period even though the preponderance of scores is positive. Ongoing propagule studies suggest that lack of seed materials, rather than water-quality conditions, are limiting the regrowth of SAV in this portion of the river.

Patterns in each of the water-quality monitoring station segments shown in Figures 7 through 15 correspond generally to the observations made for the larger salinity zone segments. However, the inter-annual pattern of SAV coverage in the tidal Potomac River station segments suggest that peak growth years show a distinct upstream-downstream gradient, suggested a strong relation to in-stream conditions, rather than external forcing.

The patterns in the Chesapeake Bay habitat criteria scores in relation to SAV coverage in each respective segment indicate that satisfaction of the SAV habitat criteria independently present neither necessary nor sufficient conditions for SAV to occur.

SUMMARY

Potomac River segments were assigned an annual (growing season median) score in reference to how well the water-quality conditions satisfied the SAV habitat criteria that were established for the Chesapeake Bay in 1992. Parameters included in the criteria are light attenuation, dissolved inorganic nitrogen, dissolved inorganic phosphorus, total suspended solids, and chlorophyll-a. SAV was generally present when SAV habitat criteria were met, but these criteria were not the only determining factors for fluctuations

in SAV areal coverage. For example, SAV habitat criteria were met in the lower Potomac Estuary for 1983-1997, yet SAV areal coverage was minimal.

REFERENCES CITED

Batiuk, R.A., Orth, R. J., Moore, K.A., Dennison, W.C., Stevenson, J.C., Staver, L. W., Carter, V., Rybicki, N. B., Hickman, R. E., Kollar, S., Bieber, S., and Heasly, P., 1992, Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A Technical Synthesis: Chesapeake Bay Program, U.S. Environmental Protection Agency, Annapolis, Maryland, 186 p with appendixes.

Carter, Virginia, and Rybicki, N.B., 1986, Resurgence of submersed aquatic macrophytes in the tidal Potomac River, Maryland, Virginia, and District of Columbia: Estuaries, v. 9, no. 4B, p. 368-375.

Carter, Virginia, and Rybicki, N.B., 1992, V. Regional SAV Study Area Findings – Upper Potomac River, in Batiuk, R.A. and others, Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A Technical Synthesis: Chesapeake Bay Program, U.S. Environmental Protection Agency, Annapolis, Maryland, p. 55-77.

Landwehr, J.M., Carter, Virginia, and Rybicki, N.B., 1997, The re-emergence of submersed aquatic vegetation in the Potomac River in response to environmental and climatic factors: EOS, v. 78, no. 17, p. S124.

Orth, Robert J., Nowak, J.N., and Wilcox, D., 1997, Distribution of submerged aquatic vegetation in the Chesapeake Bay and tributaries and Coastal Bays, 1996: Virginia Institute of Marine Science, The College of William and Mary, Gloucester Point, Virginia, 300 p.

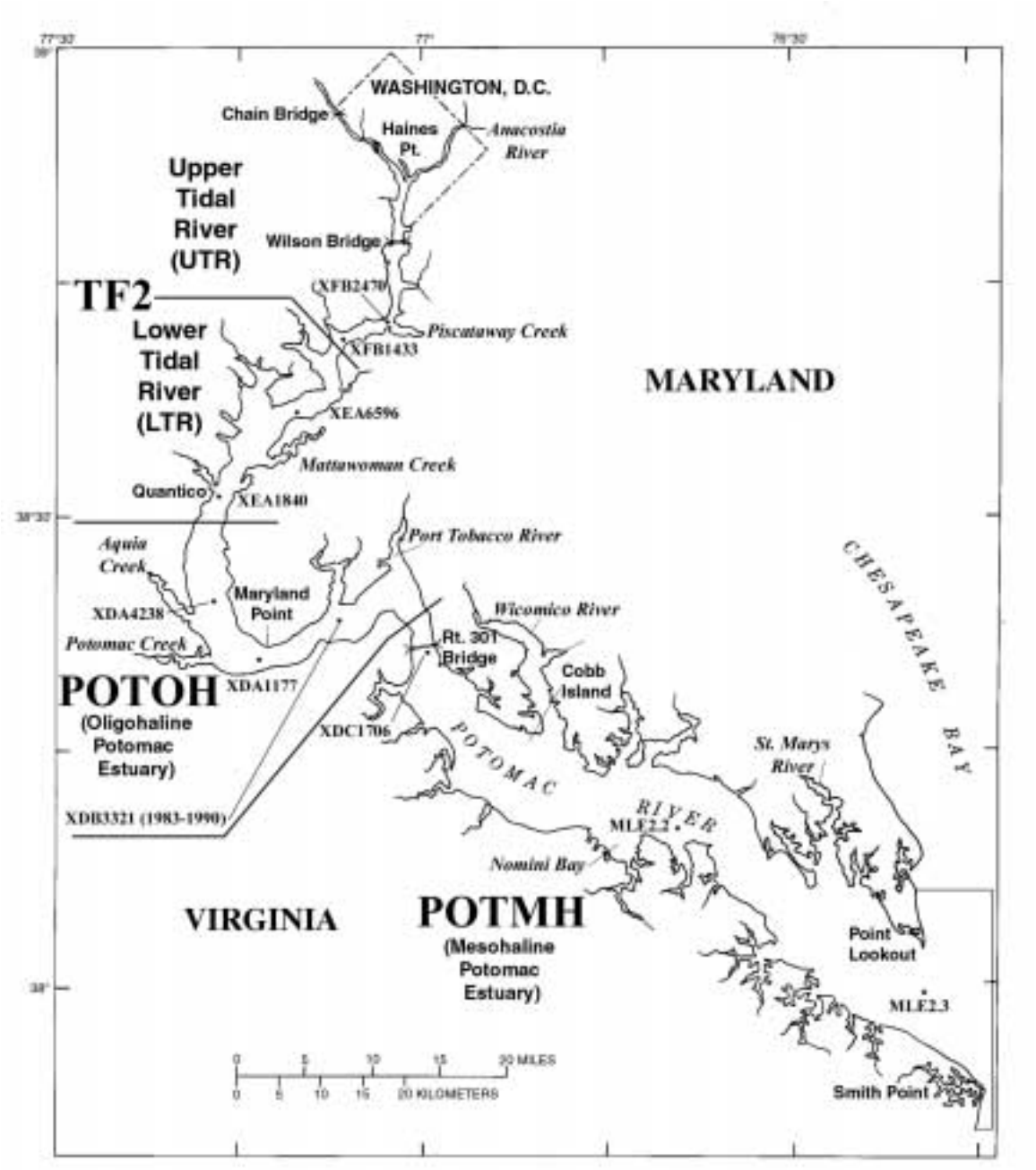

Figure 1. Map – Chesapeake Bay Program segments and stations for the tidal Potomac River and Potomac Estuary. Station numbers correspond to State of Maryland Department of Natural Resources mainstem monitoring stations.

Table 1. Abbreviations for terms used throughout the report

Term	Abbreviation
Secchi depth, in meters (m)	SECCHI
Total suspended solids, in milligrams per liter (mg/l)	TSS
Chlorophyll-a, in micrograms per liter (µg/l)	CHLA
Dissolved inorganic phosphorus, in milligrams per liter (mg/l)	DIP
Dissolved inorganic nitrogen, in milligrams per liter (mg/l)	DIN
Submersed aquatic vegetation	SAV
Freshwater tidal Potomac River segment	TF2
Upper tidal Potomac River segment	UTR
Lower tidal Potomac River segment	LTR
Oligohaline Potomac Estuary segment	POTOH
Mesohaline Potomac Estuary segment	POTMH
State of Maryland Department of Natural Resources	MD DNR
Chesapeake Bay Program	CBP

Table 2. Surface area, in hectares, covered by submersed aquatic vegetation in the tidal Potomac River and Potomac Estuary for the period 1983 through 1997, for USGS segments UTR and LTR, and Chesapeake Bay Program segments TF2, POTOH, and POTMH (n.d. = no data; see Figure 1 for location of river segments)

YEAR	UTR	LTR	TF2	POTOH	POTMH
1983	200.00	0.00	200.00	n.d.	n.d.
1984	619.51	0.00	619.51	217.09	59.90
1985	1375.50	0.41	1375.91	431.80	55.61
1986	1554.20	56.54	1610.74	383.87	43.12
1987	1465.06	113.17	1578.23	484.95	49.64
1988	1267.00	140.00	1407.00	434.00	n.d.
1989	586.75	717.55	1304.30	1216.19	100.83
1990	627.81	1010.95	1638.75	1308.19	108.77
1991	837.09	1207.11	2044.20	1414.87	136.75
1992	435.99	976.42	1412.41	1501.17	96.58
1993	479.01	933.85	1412.86	1296.74	110.07
1994	412.29	569.97	982.26	1255.18	194.55
1995	419.17	224.45	643.61	1023.53	239.17
1996	272.40	470.28	742.69	1036.66	402.40
1997	364.41	363.23	727.64	1206.26	666.84

Table 3. Surface area, in hectares, covered by submersed aquatic vegetation in the tidal Potomac River and Potomac Estuary for the period 1983 through 1997, for water-quality monitoring station segments (n.d. = no data; see Figure 1 for location of monitoring stations)

YEAR	XFB2470	XFB1433	XEA6596	XEA1840	XDA4238	XDA1177	XDC1706	MLE2.2	MLE2.3
1983	0.00	0.00	0.00	0.00	n.d.	n.d.	n.d.	n.d.	n.d.
1984	254.82	30.19	0.00	0.00	0.00	17.13	4.48	0.00	0.00
1985	499.35	108.99	0.41	8.99	5.41	22.35	5.61	0.00	2.18
1986	647.21	171.63	2.14	10.31	7.08	16.41	7.56	0.00	0.69
1987	618.33	136.62	10.05	33.59	4.84	12.13	19.97	0.00	0.00
1988	540.00	146.00	9.00	94.00	15.00	4.00	n.d.	n.d.	n.d.
1989	81.15	118.07	31.77	232.72	55.96	49.09	54.65	0.00	0.00
1990	101.92	113.28	42.55	333.04	207.70	49.17	54.70	0.00	0.00
1991	222.23	156.97	74.44	342.48	201.22	61.03	53.33	0.00	0.00
1992	45.63	45.61	60.09	337.19	163.86	71.16	49.52	0.00	0.00
1993	39.47	45.54	71.74	351.54	172.17	75.28	50.86	0.00	0.00
1994	40.11	15.24	21.68	298.49	157.61	76.87	59.35	0.00	0.00
1995	46.53	16.06	16.77	71.03	78.94	82.14	57.51	21.69	0.00
1996	49.70	24.19	37.89	87.60	64.20	58.05	60.63	49.51	0.00
1997	122.41	30.62	36.16	24.25	49.46	35.06	71.97	63.74	0.00

Table 4. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters in freshwater tidal Potomac River segment UTR for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (µg/l)	DIP (mg/l)
1983	0.66	12.5	5.56	0.0300
1984	0.76	10.0	8.26	0.0200
1985	0.91	14.5	7.98	0.0400
1986	0.60	15.0	7.35	0.0200
1987	0.70	14.0	8.37	0.0300
1988	0.60	19.0	7.03	0.0220
1989	0.50	15.5	6.88	0.0380
1990	0.60	18.0	8.52	0.0320
1991	0.70	15.5	8.97	0.0160
1992	0.60	18.0	7.85	0.0230
1993	0.60	19.5	12.71	0.0130
1994	0.60	17.0	18.44	0.0205
1995	0.70	20.0	19.94	0.0160
1996	0.60	23.0	8.65	0.0215
1997	0.60	20.5	20.50	0.0125

Table 5. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters in freshwater tidal Potomac River segment LTR for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (µg/l)	DIP (mg/l)
1983	0.61	18.0	9.68	0.0400
1984	0.67	18.0	25.66	0.0200
1985	0.61	15.0	24.44	0.0375
1986	0.50	17.5	12.79	0.0320
1987	0.75	14.0	7.73	0.0290
1988	0.75	15.7	6.48	0.0290
1989	0.80	11.5	5.21	0.0250
1990	0.60	17.0	4.38	0.0300
1991	0.80	9.0	4.80	0.0185
1992	0.70	15.0	3.99	0.0300
1993	0.70	15.5	4.98	0.0255
1994	0.60	19.3	12.96	0.0255
1995	0.60	22.0	17.57	0.0233
1996	0.50	27.5	11.04	0.0185
1997	0.45	26.3	25.08	0.0148

Table 6. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters in freshwater tidal Potomac River segment TF2 for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (μg/l)	DIP (mg/l)
1983	0.61	16.5	5.94	0.0400
1984	0.75	14.0	12.03	0.0200
1985	0.70	15.0	18.04	0.0400
1986	0.60	16.0	9.87	0.0240
1987	0.70	14.0	7.78	0.0300
1988	0.70	17.0	7.03	0.0240
1989	0.60	13.5	5.68	0.0325
1990	0.60	18.0	5.38	0.0300
1991	0.75	11.8	6.12	0.0160
1992	0.70	17.0	5.23	0.0260
1993	0.60	17.5	10.02	0.0165
1994	0.60	18.0	15.20	0.0225
1995	0.70	20.8	18.89	0.0190
1996	0.50	25.8	10.02	0.0210
1997	0.50	21.3	24.30	0.0130

Table 7. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters in oligohaline Potomac Estuary segment POTOH for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (μg/l)	DIP (mg/l)
1983	0.82	10.5	2.67	0.0500
1984	0.66	16.0	26.62	0.0600
1985	0.61	18.0	6.81	0.0600
1986	0.60	15.5	3.61	0.0640
1987	0.65	15.0	3.89	0.0475
1988	0.70	13.0	4.19	0.0540
1989	0.50	15.5	3.74	0.0480
1990	0.45	21.0	3.42	0.0500
1991	0.80	12.0	5.78	0.0300
1992	0.60	16.3	3.36	0.0470
1993	0.60	19.3	4.02	0.0448
1994	0.50	21.0	4.86	0.0463
1995	0.58	20.8	6.15	0.0375
1996	0.40	30.5	8.83	0.0258
1997	0.50	25.3	11.85	0.0270

Table 8. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters in mesohaline Potomac Estuary segment POTMH for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (μg/l)	DIP (mg/l)	DIN (mg/l)
1983	0.88	7.5	2.83	0.0400	0.5860
1984	0.87	6.0	8.03	0.0400	0.1895
1985	1.15	8.1	7.06	0.0200	0.1195
1986	1.20	6.0	7.33	0.0100	0.2100
1987	1.20	6.0	9.12	0.0070	0.2500
1988	1.15	8.0	13.46	0.0080	0.1495
1989	1.10	8.0	10.39	0.0090	0.4035
1990	1.00	11.0	8.82	0.0080	0.2700
1991	1.25	7.0	7.18	0.0045	0.1390
1992	1.40	12.0	5.98	0.0090	0.2330
1993	1.20	8.0	8.01	0.0100	0.1400
1994	1.15	7.6	9.12	0.0065	0.1760
1995	1.40	12.5	7.18	0.0080	0.1435
1996	1.00	12.0	13.23	0.0090	0.6320
1997	1.00	13.0	11.10	0.0070	0.2155

Table 9. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters at freshwater tidal Potomac River monitoring station XFB2470 for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (μg/l)	DIP (mg/l)	DIN (mg/l)
1983	0.76	12.0	9.33	0.0300	1.9040
1984	0.87	10.0	4.97	0.0300	2.1335
1985	1.01	12.5	6.74	0.0400	2.0330
1986	0.70	13.0	6.76	0.0180	1.8540
1987	0.80	14.0	6.88	0.0310	2.0680
1988	0.65	21.5	6.06	0.0210	2.5440
1989	0.50	15.0	6.80	0.0380	2.1120
1990	0.60	18.0	9.57	0.0320	2.0520
1991	0.60	14.5	8.72	0.0160	2.5720
1992	0.60	19.0	7.85	0.0250	2.4120
1993	0.60	19.0	14.45	0.0120	2.1000
1994	0.60	15.5	14.95	0.0215	1.9045
1995	0.70	19.5	18.19	0.0160	1.7640
1996	0.60	22.5	9.79	0.0225	1.6395
1997	0.65	19.0	18.40	0.0140	1.6070

Table 10. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters at freshwater tidal Potomac River monitoring station XFB1433 for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (µg/l)	DIP (mg/l)	DIN (mg/l)
1983	0.66	18.0	5.56	0.0300	1.8690
1984	0.76	11.0	9.71	0.0200	1.9840
1985	0.85	15.0	16.27	0.0400	1.7940
1986	0.60	15.0	8.37	0.0200	1.7520
1987	0.60	15.0	8.97	0.0300	1.9610
1988	0.60	17.5	8.15	0.0230	2.2200
1989	0.55	16.0	8.67	0.0380	2.0760
1990	0.55	18.0	7.48	0.0280	2.1100
1991	0.70	16.0	9.22	0.0140	2.2600
1992	0.65	17.5	8.22	0.0210	2.1720
1993	0.60	20.0	11.96	0.0140	2.0100
1994	0.60	18.5	20.19	0.0190	1.6230
1995	0.70	25.5	22.18	0.0160	1.6550
1996	0.55	23.0	7.92	0.0215	1.6095
1997	0.50	22.5	28.60	0.0120	1.1480

Table 11. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters at freshwater tidal Potomac River monitoring station XEA6596 for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (µg/l)	DIP (mg/l)	DIN (mg/l)
1983	0.53	24.0	16.68	0.0400	1.6110
1984	0.70	15.5	22.13	0.0200	1.4420
1985	0.61	14.0	24.55	0.0300	1.4200
1986	0.50	16.0	12.86	0.0280	1.3880
1987	0.65	14.5	9.79	0.0290	1.5860
1988	0.65	19.0	14.35	0.0230	1.7760
1989	0.65	12.0	8.01	0.0180	1.9680
1990	0.60	16.0	5.68	0.0280	2.0600
1991	0.80	9.5	5.48	0.0145	1.8520
1992	0.70	15.0	6.98	0.0160	1.7160
1993	0.60	16.5	14.08	0.0175	1.4500
1994	0.60	20.0	21.93	0.0225	1.4715
1995	0.60	23.0	22.13	0.0160	1.1295
1996	0.50	22.5	9.57	0.0200	1.4750
1997	0.45	27.5	23.00	0.0130	1.1155

Table 12. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters at freshwater tidal Potomac River monitoring station XEA1840 for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (μg/l)	DIP (mg/l)	DIN (mg/l)
1983	0.66	16.0	3.96	0.0400	1.4210
1984	0.67	21.0	32.72	0.0200	0.8440
1985	0.61	15.0	19.11	0.0400	0.8908
1986	0.50	17.8	10.73	0.0405	1.0150
1987	0.80	11.0	6.06	0.0303	1.4200
1988	0.90	13.0	4.26	0.0305	1.4560
1989	0.80	11.0	3.81	0.0290	1.9410
1990	0.60	17.8	3.19	0.0320	1.7450
1991	1.00	8.0	4.26	0.0240	1.4820
1992	0.70	15.0	2.49	0.0365	1.6470
1993	0.70	14.5	3.64	0.0333	1.1235
1994	0.60	17.8	9.78	0.0295	1.1710
1995	0.65	20.0	14.32	0.0280	0.9438
1996	0.45	27.8	12.75	0.0173	1.4240
1997	0.45	23.0	25.40	0.0200	0.6940

Table 13. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters at oligohaline Potomac Estuary monitoring station XDA4238 for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (μg/l)	DIP (mg/l)	DIN (mg/l)
1983	0.82	11.0	3.69	0.0500	1.2300
1984	0.66	16.0	20.69	0.0600	0.7580
1985	0.49	19.5	6.36	0.0600	0.8240
1986	0.55	18.5	3.84	0.0680	0.8530
1987	0.70	15.0	3.14	0.0475	1.1980
1988	0.60	13.0	4.34	0.0540	0.8700
1989	0.60	12.0	2.99	0.0450	1.8480
1990	0.40	21.0	3.42	0.0500	1.5040
1991	0.80	11.5	7.10	0.0260	0.6460
1992	0.55	16.0	4.17	0.0440	1.3100
1993	0.60	20.5	3.46	0.0380	0.7200
1994	0.45	25.0	4.86	0.0465	0.9550
1995	0.63	19.5	6.48	0.0340	0.9335
1996	0.40	28.0	8.22	0.0235	1.3705
1997	0.45	26.0	13.50	0.0270	0.5865

Table 14. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters at oligohaline Potomac Estuary monitoring station XDA1177 for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (μg/l)	DIP (mg/l)	DIN (mg/l)
1983	0.82	10.0	2.46	0.0500	1.2200
1984	0.62	22.0	28.87	0.0700	0.5150
1985	0.61	17.0	8.75	0.0600	0.6590
1986	0.60	13.6	3.29	0.0590	0.7230
1987	0.55	15.0	4.49	0.0470	1.0070
1988	0.80	13.0	3.74	0.0540	0.6720
1989	0.50	18.0	4.34	0.0540	1.5240
1990	0.50	20.0	3.36	0.0500	1.2460
1991	0.75	13.5	5.63	0.0330	0.4910
1992	0.60	17.0	3.27	0.0505	1.0850
1993	0.60	18.5	4.42	0.0475	0.5590
1994	0.55	17.5	4.24	0.0460	0.7180
1995	0.58	21.0	5.00	0.0430	0.8075
1996	0.35	34.3	8.83	0.0275	1.3613
1997	0.50	25.3	7.85	0.0275	0.5023

Table 15. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters at mesohaline Potomac Estuary monitoring station XDC1706 for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (μg/l)	DIP (mg/l)	DIN (mg/l)
1983	0.88	8.0	3.05	0.0600	0.8430
1984	0.64	10.0	7.38	0.1000	0.2870
1985	0.79	9.8	6.01	0.0600	0.3165
1986	0.80	9.8	5.46	0.0495	0.4095
1987	0.95	7.0	5.05	0.0455	0.6620
1988	0.90	11.0	6.23	0.0480	0.4920
1989	0.80	12.5	5.57	0.0575	1.0460
1990	0.70	14.5	4.86	0.0380	0.5350
1991	0.80	13.5	7.20	0.0310	0.2400
1992	0.90	14.0	5.67	0.0270	0.5120
1993	0.80	14.0	7.58	0.0475	0.3200
1994	0.60	18.5	7.73	0.0445	0.3240
1995	0.80	17.0	5.58	0.0320	0.3865
1996	0.70	19.0	9.80	0.0330	1.0190
1997	0.80	19.0	11.95	0.0165	0.2540

Table 16. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters at mesohaline Potomac Estuary monitoring station MLE2.2 for the period 1983 through 1997

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (μg/l)	DIP (mg/l)	DIN (mg/l)
1984	0.76	4.0	11.91	0.0250	0.1520
1985	1.20	10.0	10.38	0.0200	0.0800
1986	1.10	8.0	7.63	0.0100	0.1160
1987	1.10	7.0	14.20	0.0070	0.0800
1988	1.00	8.0	14.50	0.0080	0.1080
1989	1.20	13.0	22.33	0.0100	0.1560
1990	1.05	13.0	13.76	0.0060	0.1560
1991	1.15	13.0	6.95	0.0040	0.0640
1992	1.40	16.5	10.77	0.0070	0.1250
1993	1.25	11.5	8.26	0.0130	0.0490
1994	1.30	9.5	10.89	0.0075	0.0560
1995	1.60	14.5	8.75	0.0080	0.0830
1996	1.10	15.0	16.22	0.0090	0.3820
1997	1.30	19.3	12.00	0.0080	0.1735

Table 17. Seasonal (April through October) median values for submersed aquatic vegetation habitat criteria parameters at mesohaline Potomac Estuary monitoring station MLE2.3 for the period 1983 through 1997 (n.d. = no data)

YEAR	SECCHI (m)	TSS (mg/l)	CHLA (μg/l)	DIP (mg/l)	DIN (mg/l)
1983	n.d.	6.0	2.62	0.0100	0.4680
1984	2.15	4.0	7.68	0.0070	0.0760
1985	1.75	4.8	4.19	0.0028	0.0607
1986	2.20	4.4	7.48	0.0021	0.0892
1987	1.90	4.3	9.42	0.0033	0.0526
1988	1.60	7.6	13.91	0.0021	0.0336
1989	1.60	5.4	12.46	0.0032	0.1175
1990	2.00	5.2	9.72	0.0042	0.0564
1991	1.80	4.3	7.14	0.0028	0.0252
1992	2.00	4.4	5.79	0.0023	0.0328
1993	1.40	4.8	8.35	0.0028	0.0261
1994	1.40	5.9	9.12	0.0031	0.0316
1995	1.50	5.0	6.43	0.0024	0.0318
1996	1.40	4.8	13.61	0.0029	0.1510
1997	1.60	6.7	10.70	0.0028	0.0175

Table 18. Chesapeake Bay habitat criteria for the tidal Potomac River and Potomac Estuary based on Chesapeake Bay submersed aquatic vegetation (SAV) habitat requirements for one meter restoration as established by the Chesapeake Bay Program

Water-Quality Parameter	**Criteria by Salinity Regime** The median value of measurements made during the SAV growing season (April through October) for each water-quality parameter must satisfy the criterion for the specific salinity regime of the sampling site.		
	Freshwater	**Oligohaline**	**Mesohaline**
SECCHI	≥ 0.7 m *	≥ 0.7 m *	≥ 1.0 m **
TSS	≤ 15 mg/l	≤ 15 mg/l	≤ 15 mg/l
CHLA	< 15 µg/l	< 15 µg/l	< 15 µg/l l
DIP	≤0.04 mg/l	<0.07 mg/l	<0.01 mg/l
DIN	(none)	(none)	<0.15 mg/l

* This is equivalent to a criterion for the seasonal median value of the light attenuation coefficient to be ≤ 2, and for the seasonal median percent light to be ≥12.6% at 1-meter depth in the water column, assuming the Chesapeake Bay Program conversion factor, light attenuation coefficient = 1.45/SECCHI.

** This is equivalent to a criterion for the seasonal median value of the light attenuation coefficient to be ≤ 1.5, and for the seasonal median percent light to be ≥23.5% at 1-meter depth in the water column, assuming the Chesapeake Bay Program conversion factor, light attenuation coefficient = 1.45/SECCHI.

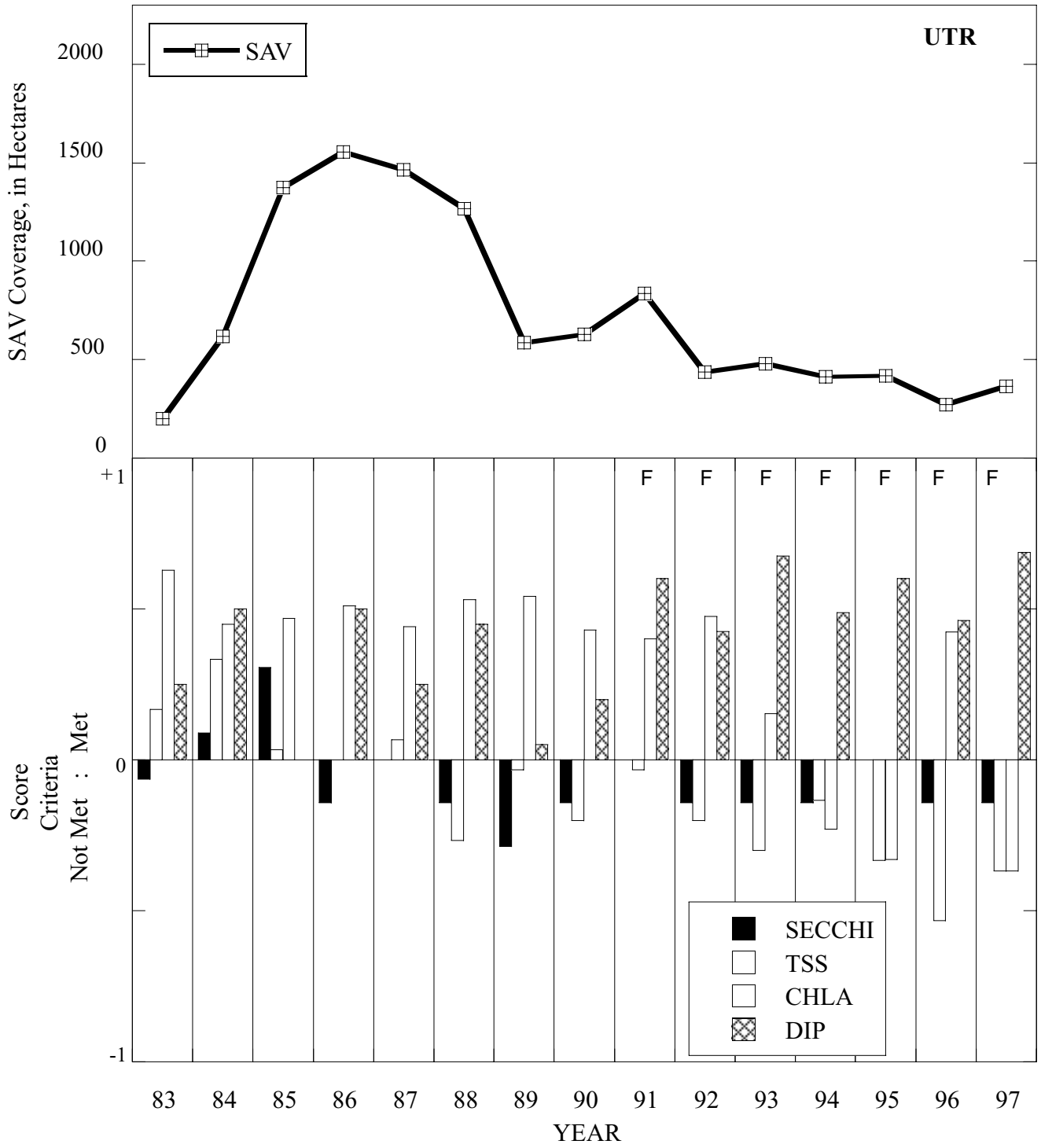

Figure 2. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores in freshwater tidal Potomac River segment UTR for the period 1983 through 1997. (F denotes use of filtered water samples for DIP.)

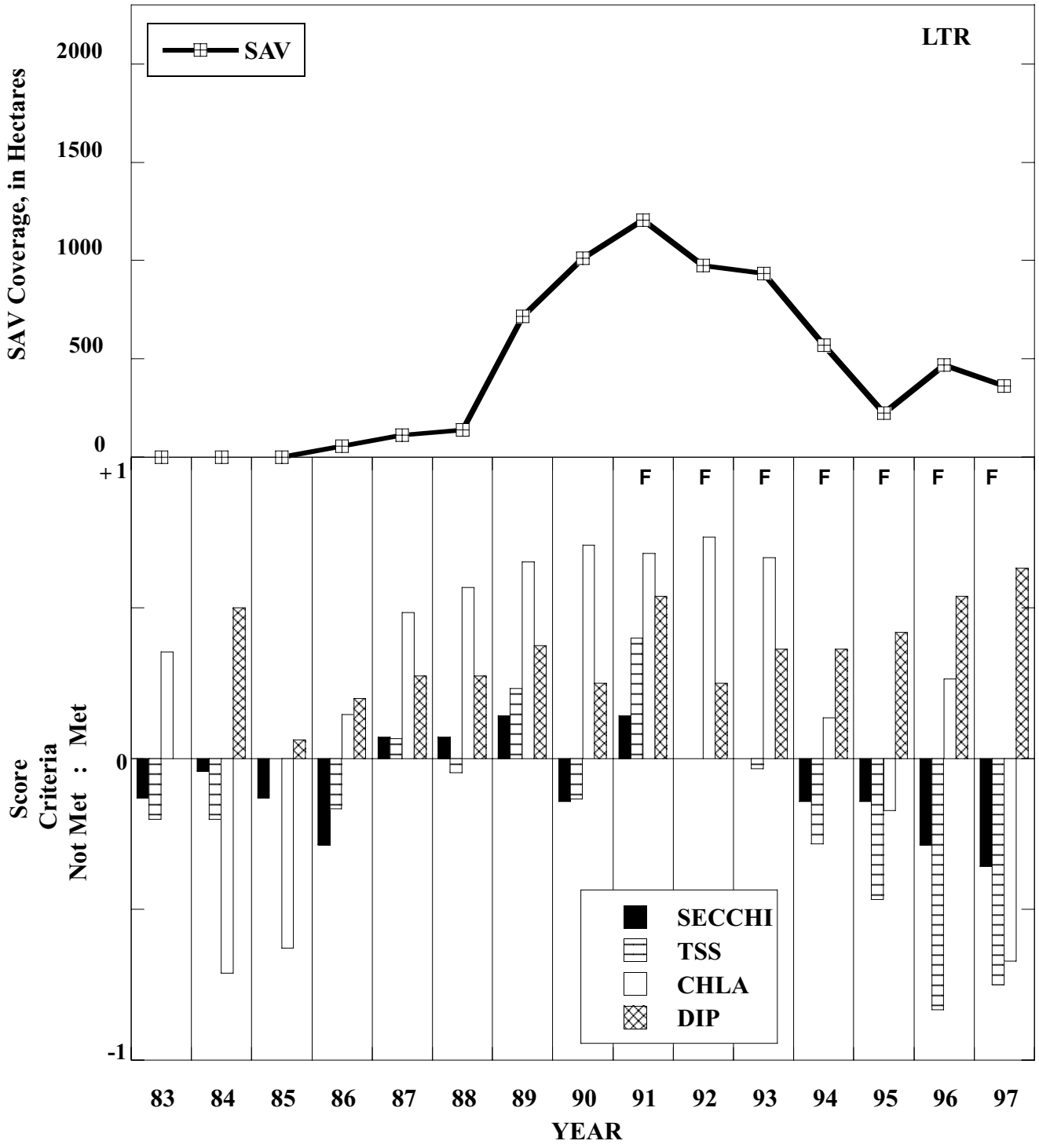

Figure 3. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores in freshwater tidal Potomac River segment LTR for the period 1983 through 1997. (F denotes use of filtered water samples for DIP.)

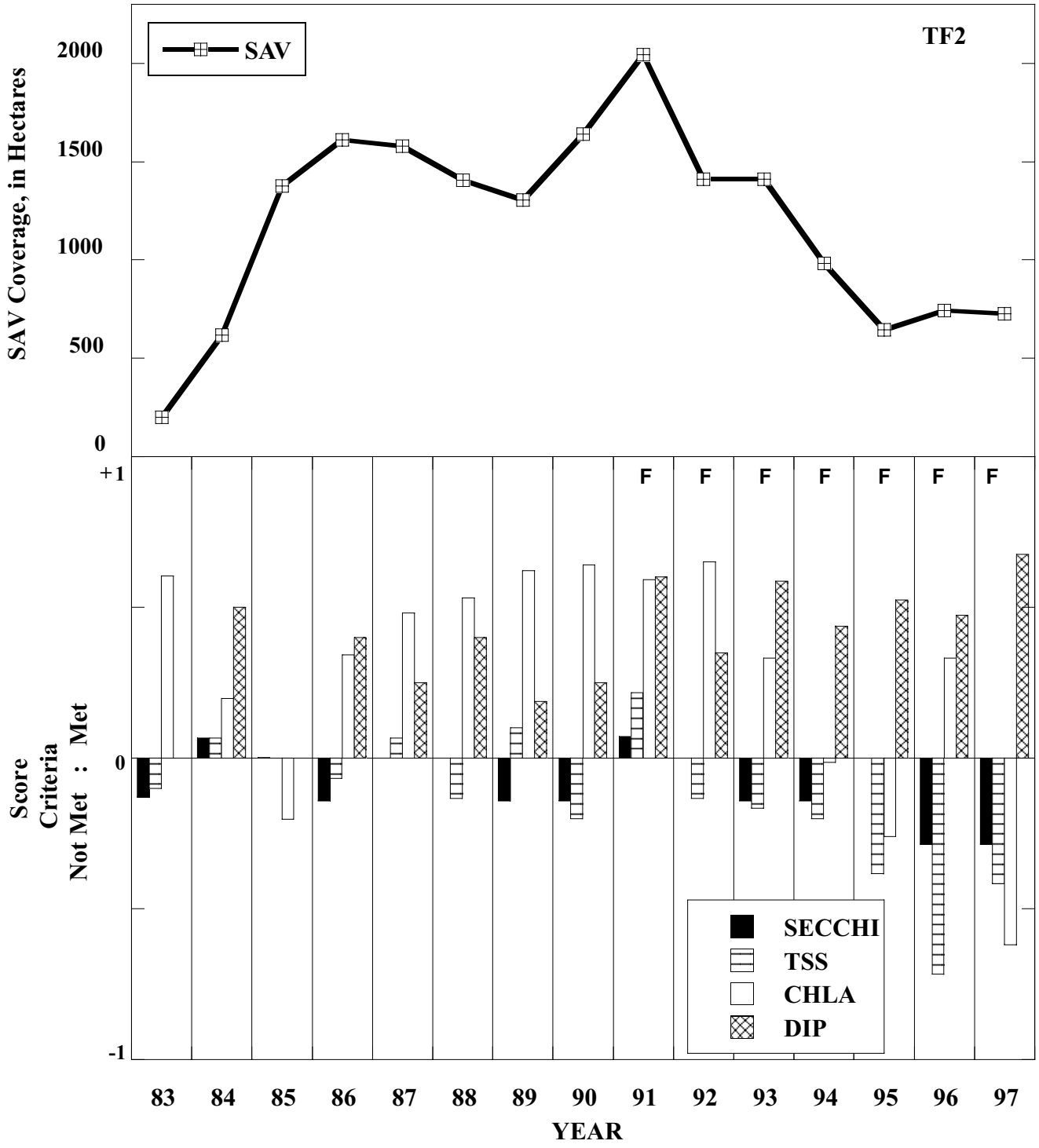

Figure 4. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores in freshwater tidal Potomac River segment TF2 for the period 1983 through 1997. (F denotes use of filtered water samples for DIP.)

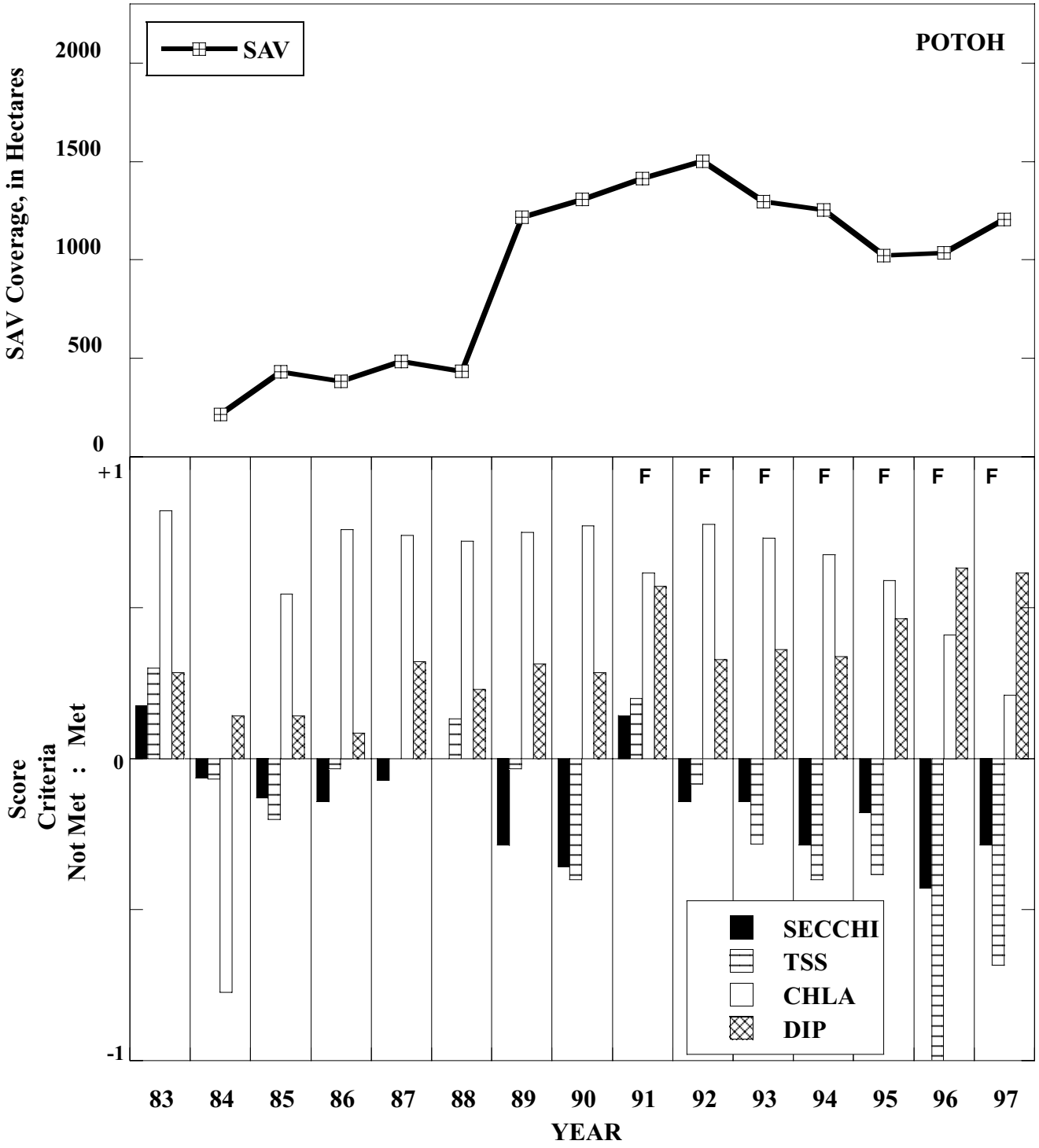

Figure 5. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores in oligohaline Potomac Estuary segment POTOH for the period 1983 through 1997. (F denotes use of filtered water samples for DIP.)

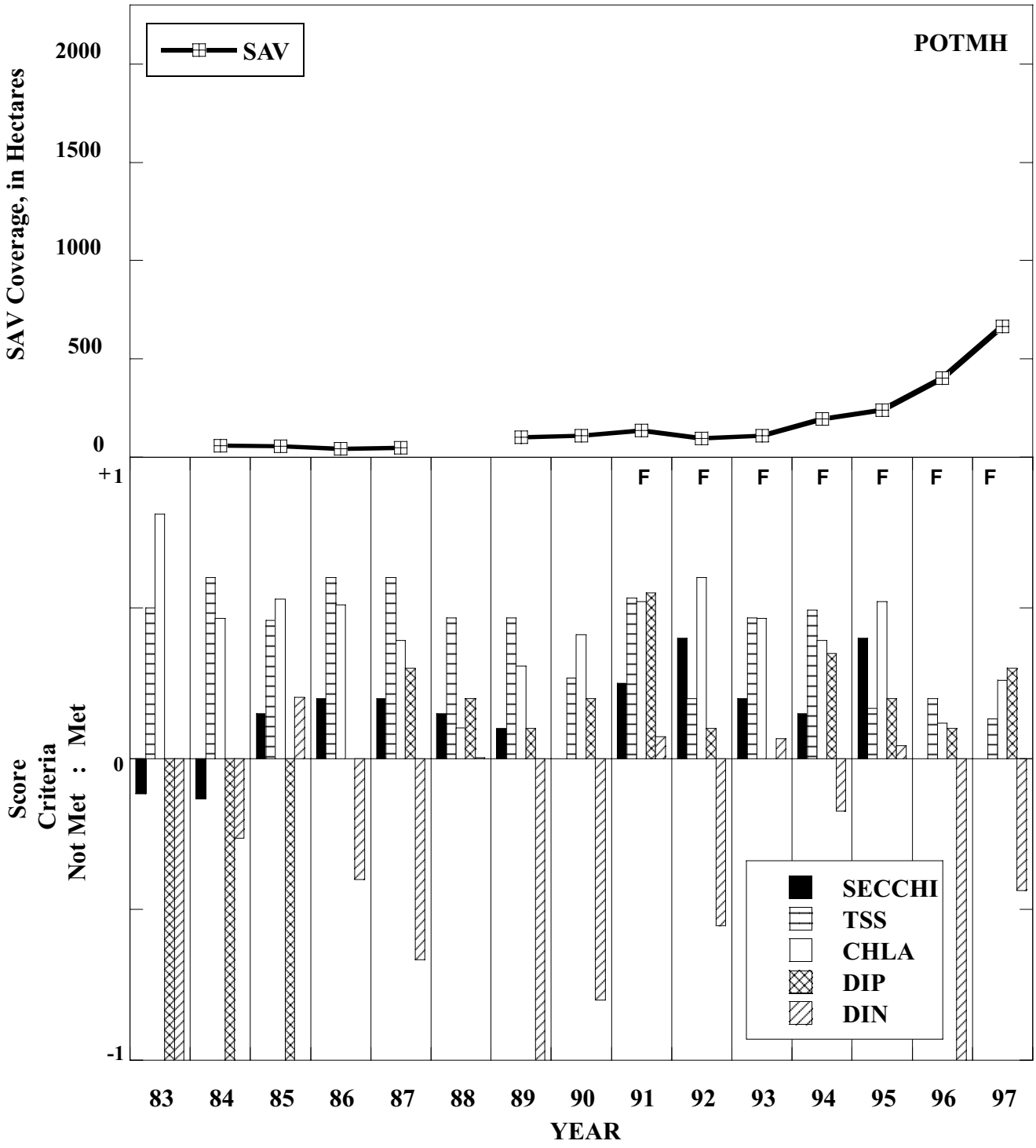

Figure 6. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores in mesohaine Potomac Estuary segment POTMH for the period 1983 through 1997. (F denotes use of filtered water samples for DIN and DIP.)

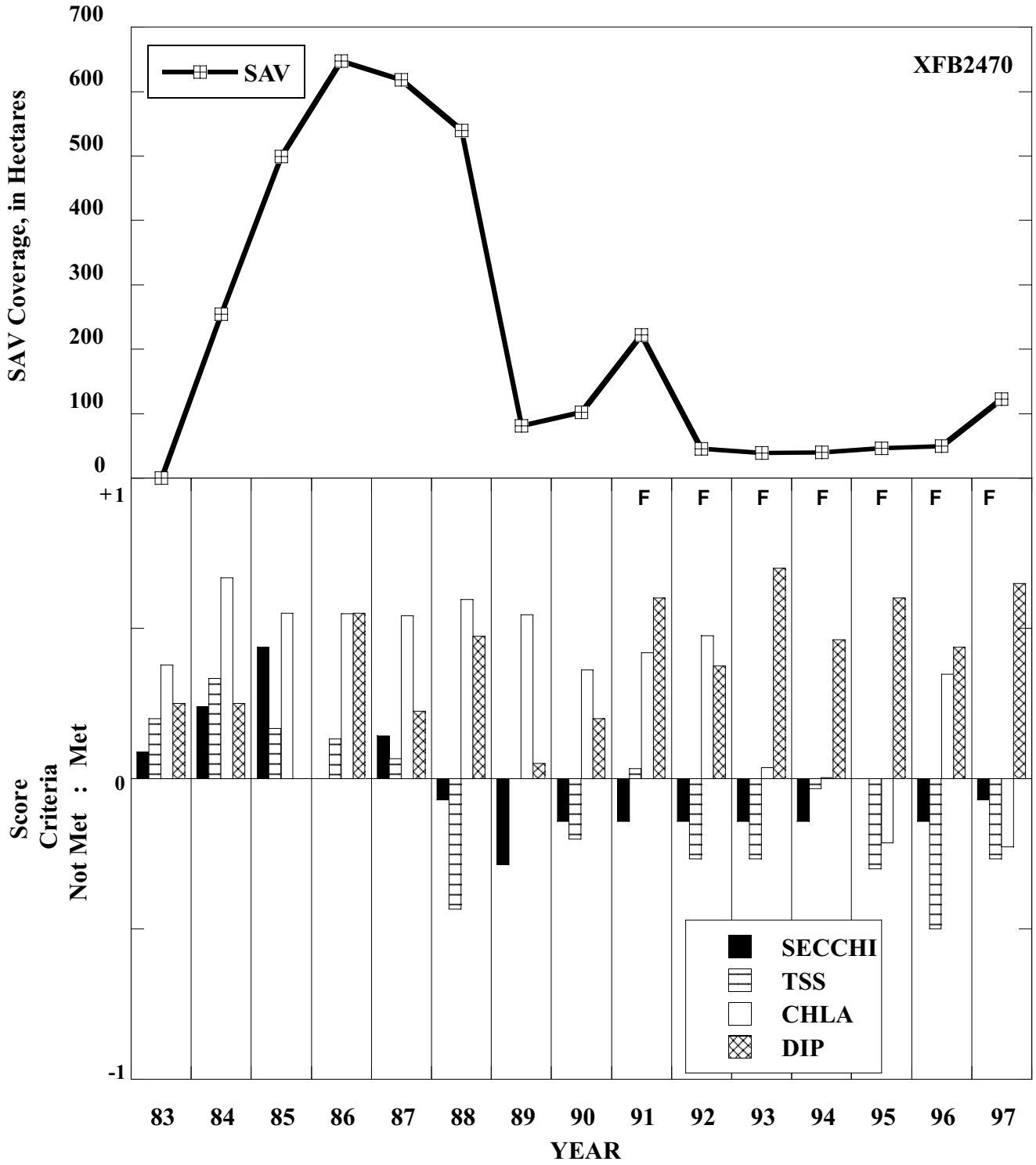

Figure 7. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores for freshwater tidal Potomac River monitoring station XFB2470 segment for the period 1983 through 1997. (F denotes use of filtered water samples for DIP.)

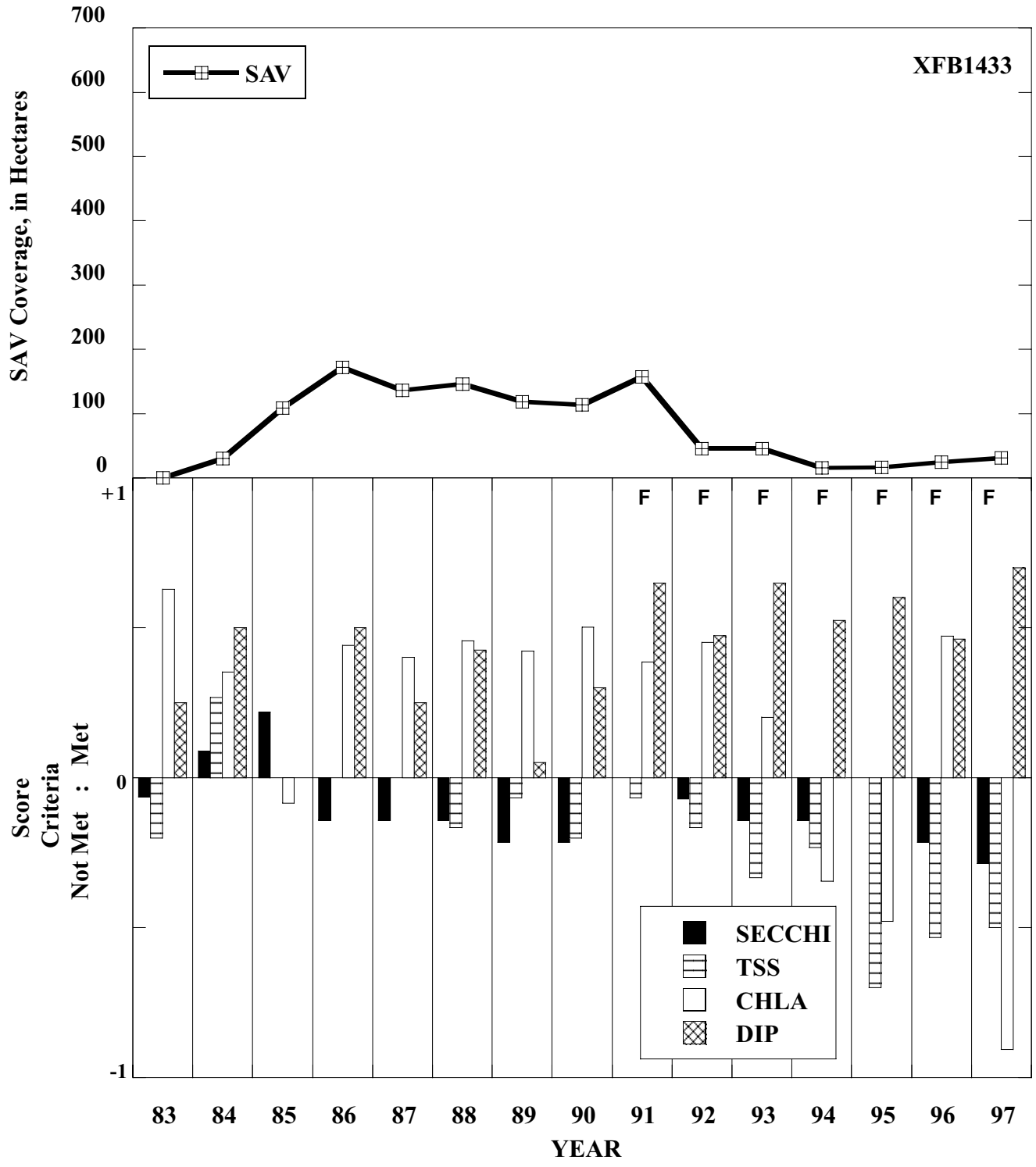

Figure 8. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores for the freshwater tidal Potomac River monitoring station XFB1433 segment for the period 1983 through 1997. (F denotes use of filtered water samples for DIP.)

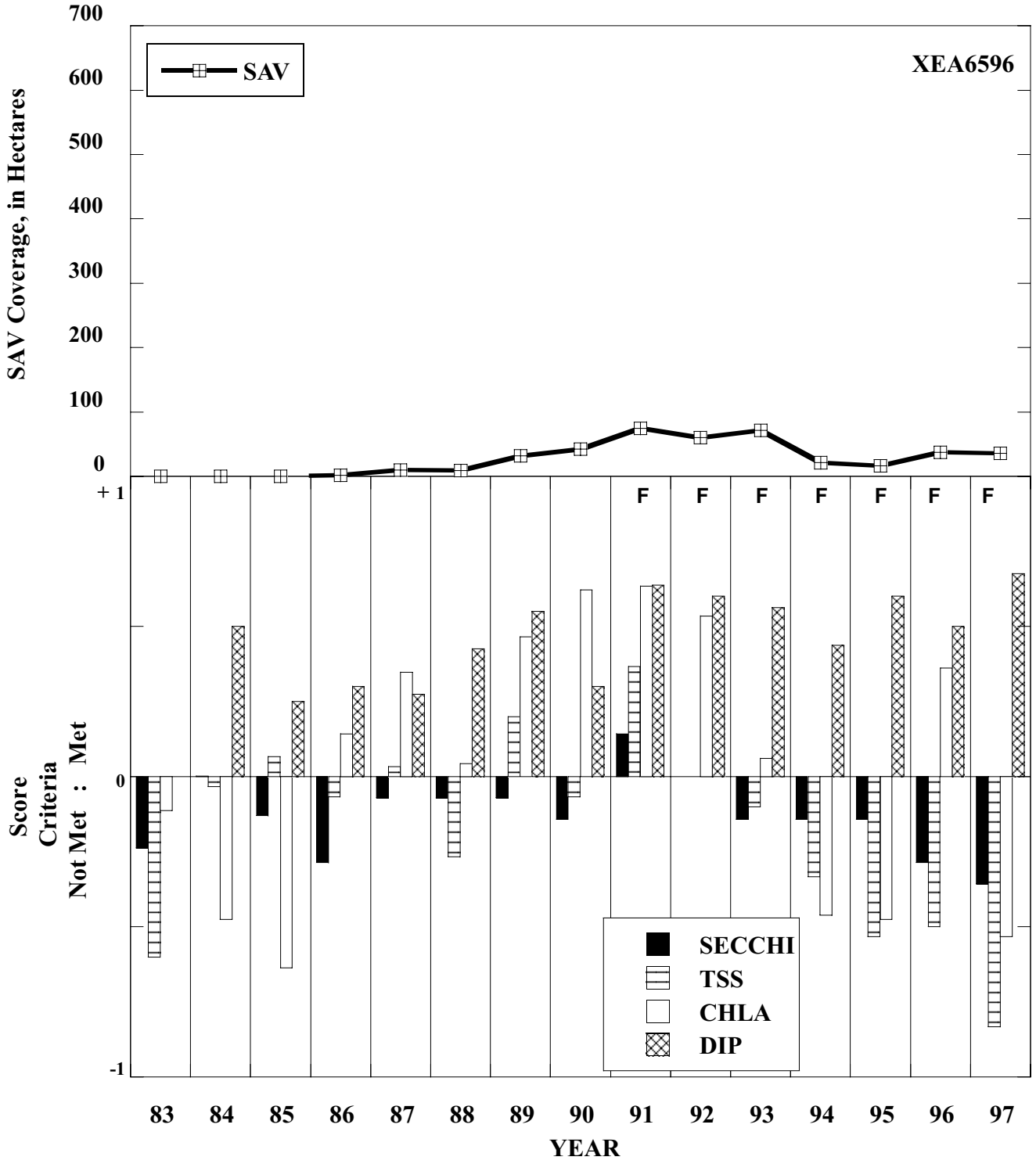

Figure 9. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores for freshwater tidal Potomac River monitoring station XEA6596 segment for the period 1983 through 1997. (F denotes use of filtered water samples for DIP.)

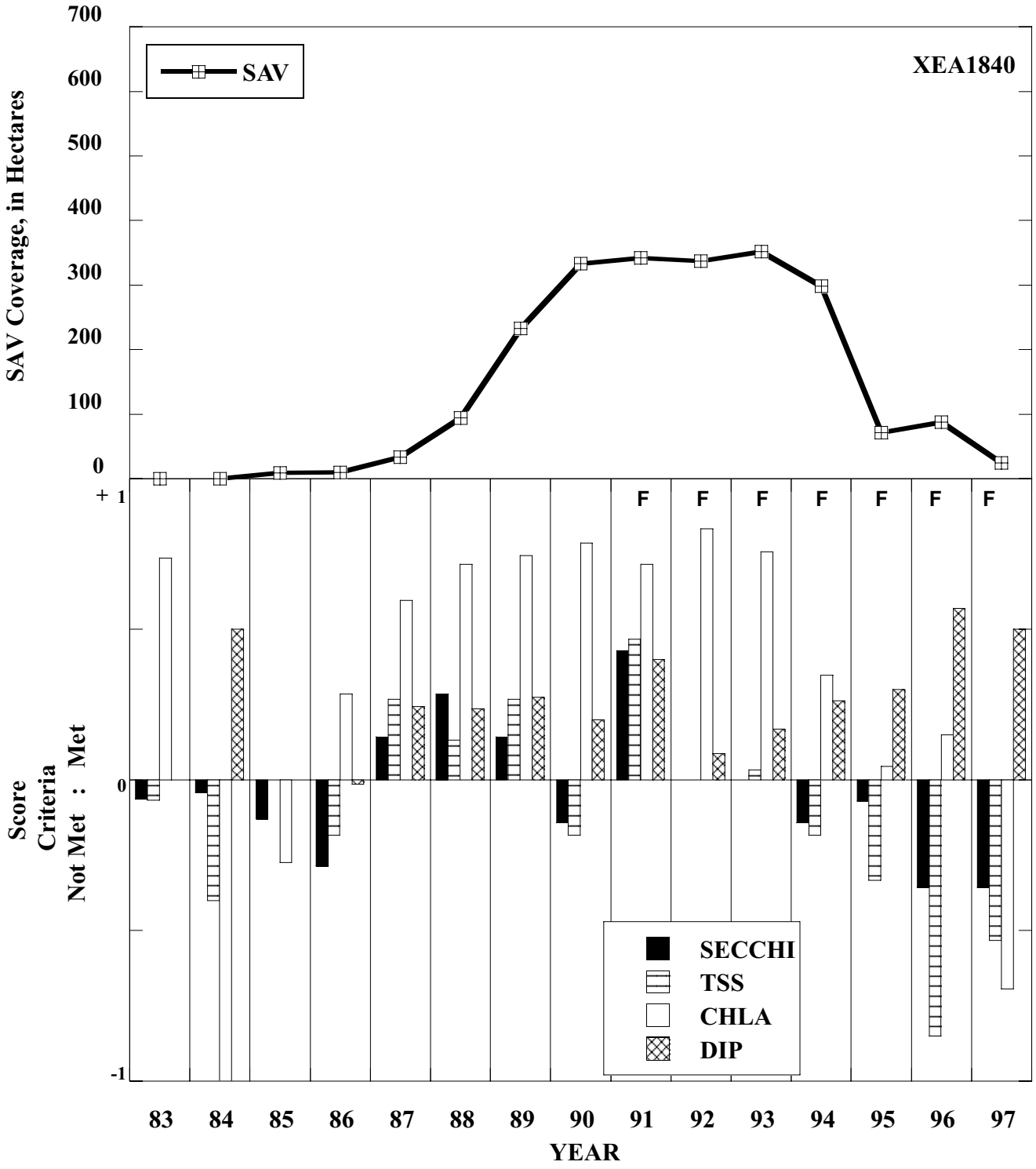

Figure 10. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores for freshwater tidal Potomac River monitoring station XEA1840 segment for the period 1983 through 1997. (F denotes use of filtered water samples for DIP.)

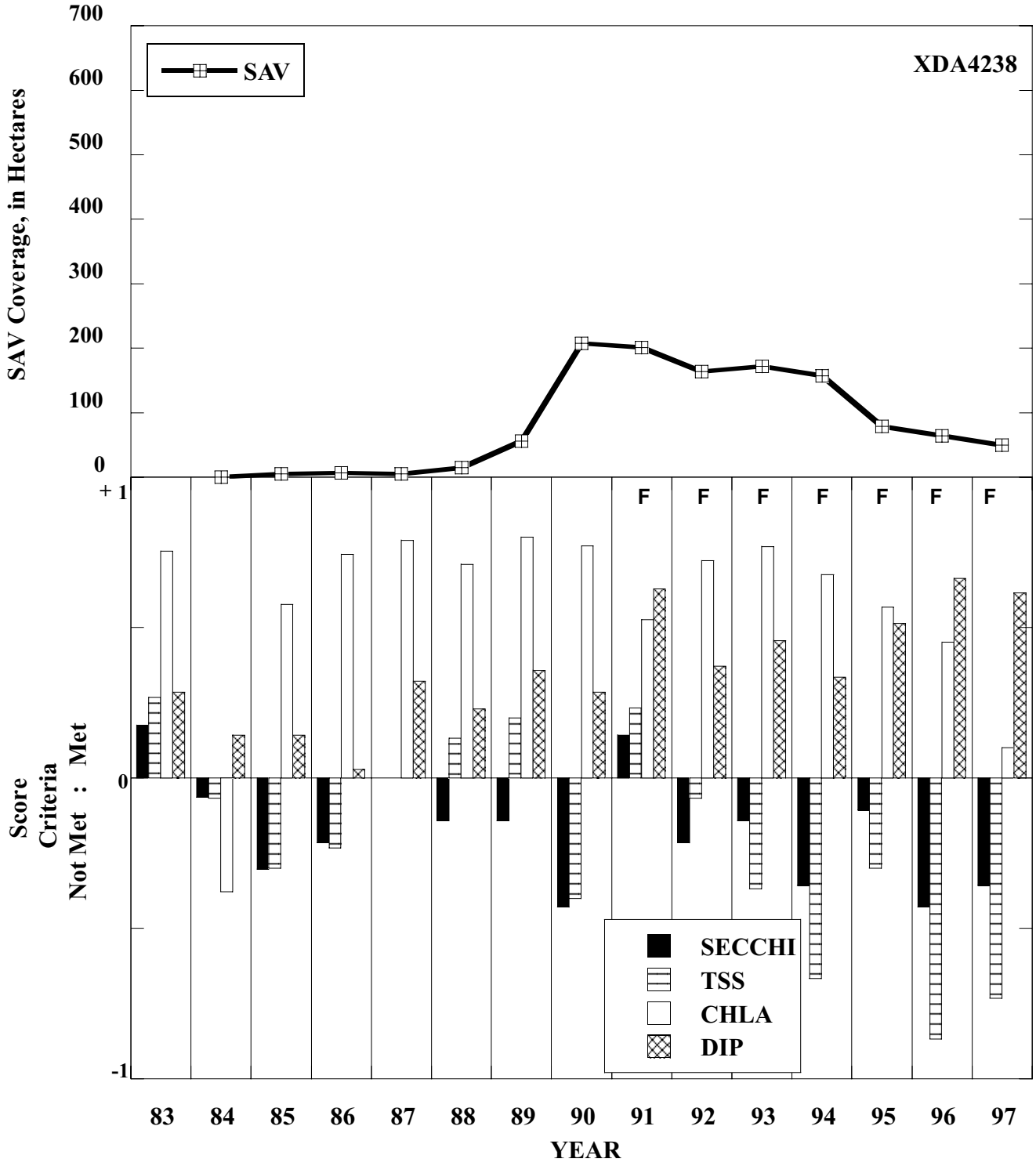

Figure 11. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores for oligohaline Potomac Estuary monitoring station XDA4238 segment for the period 1983 through 1997. (F denotes use of filtered water samples for DIP.)

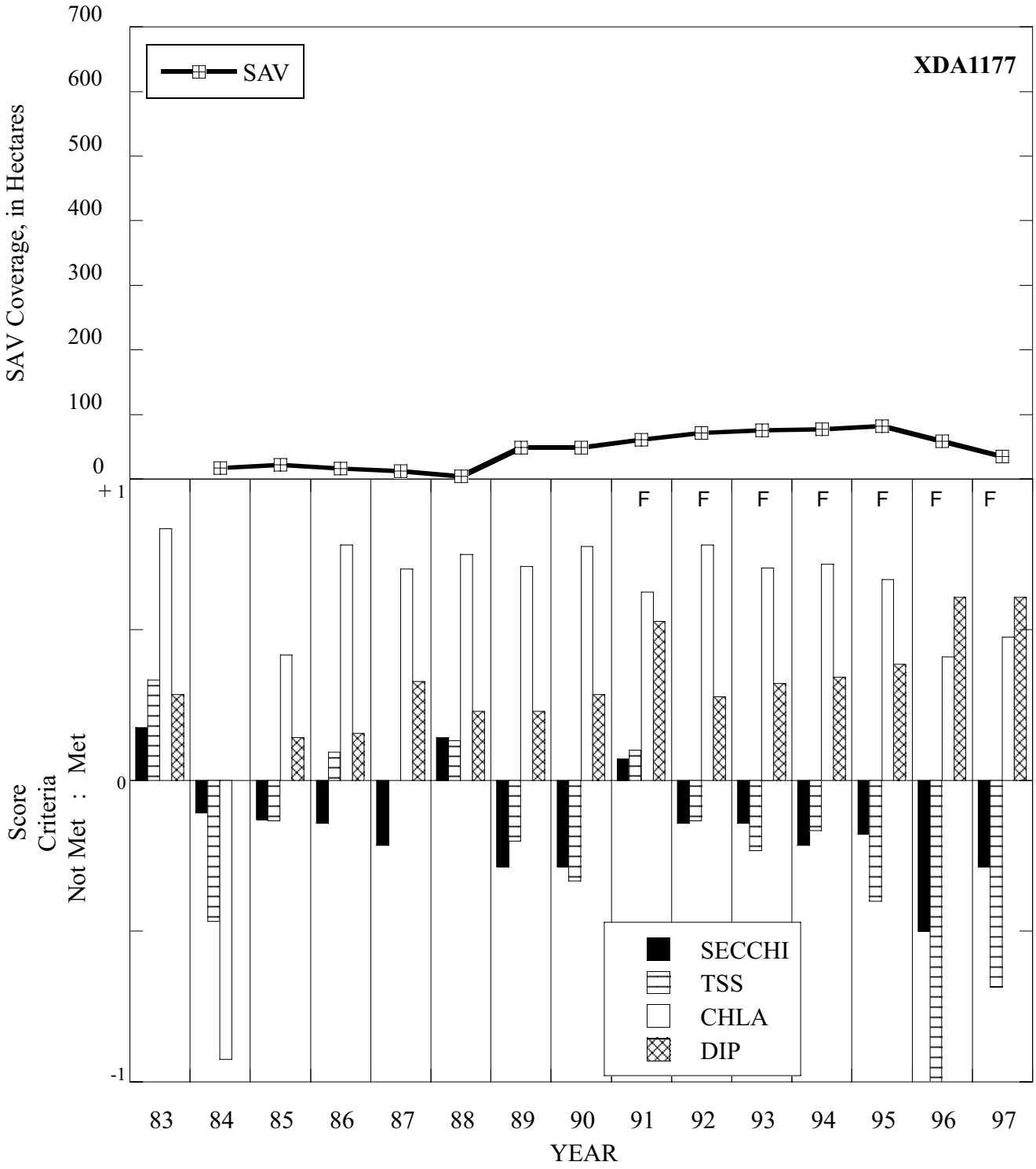

Figure 12. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores for oligohaline Potomac Estuary monitoring station XDC1177 segment for the period 1983 through 1997.
(F denotes use of filtered water samples for DIP.)

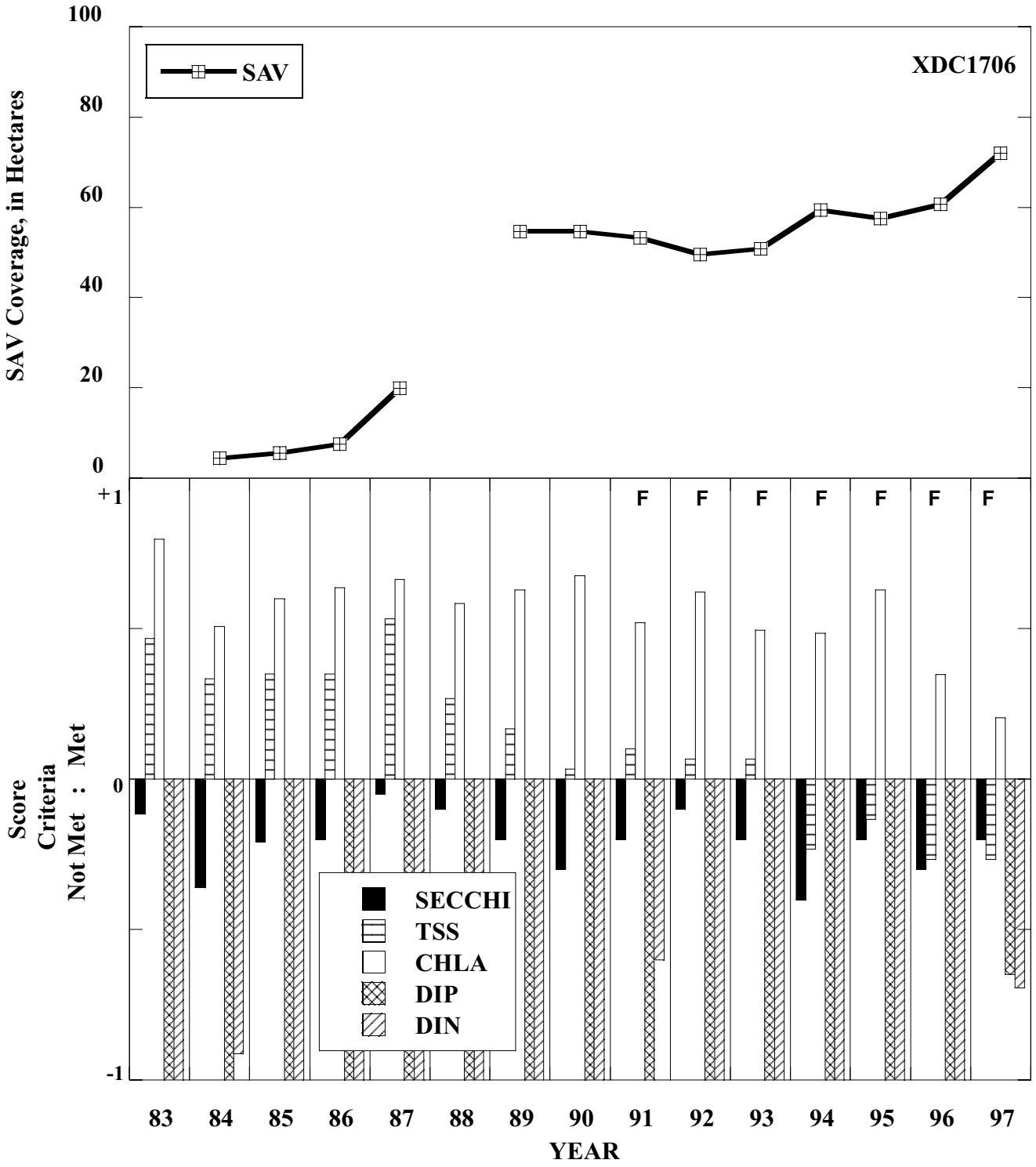

Figure 13. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores for mesohaline Potomac Estuary monitoring station XDC1706 segment for the period 1983 through 1997.
(F denotes use of filtered water samples for DIN and DIP.)

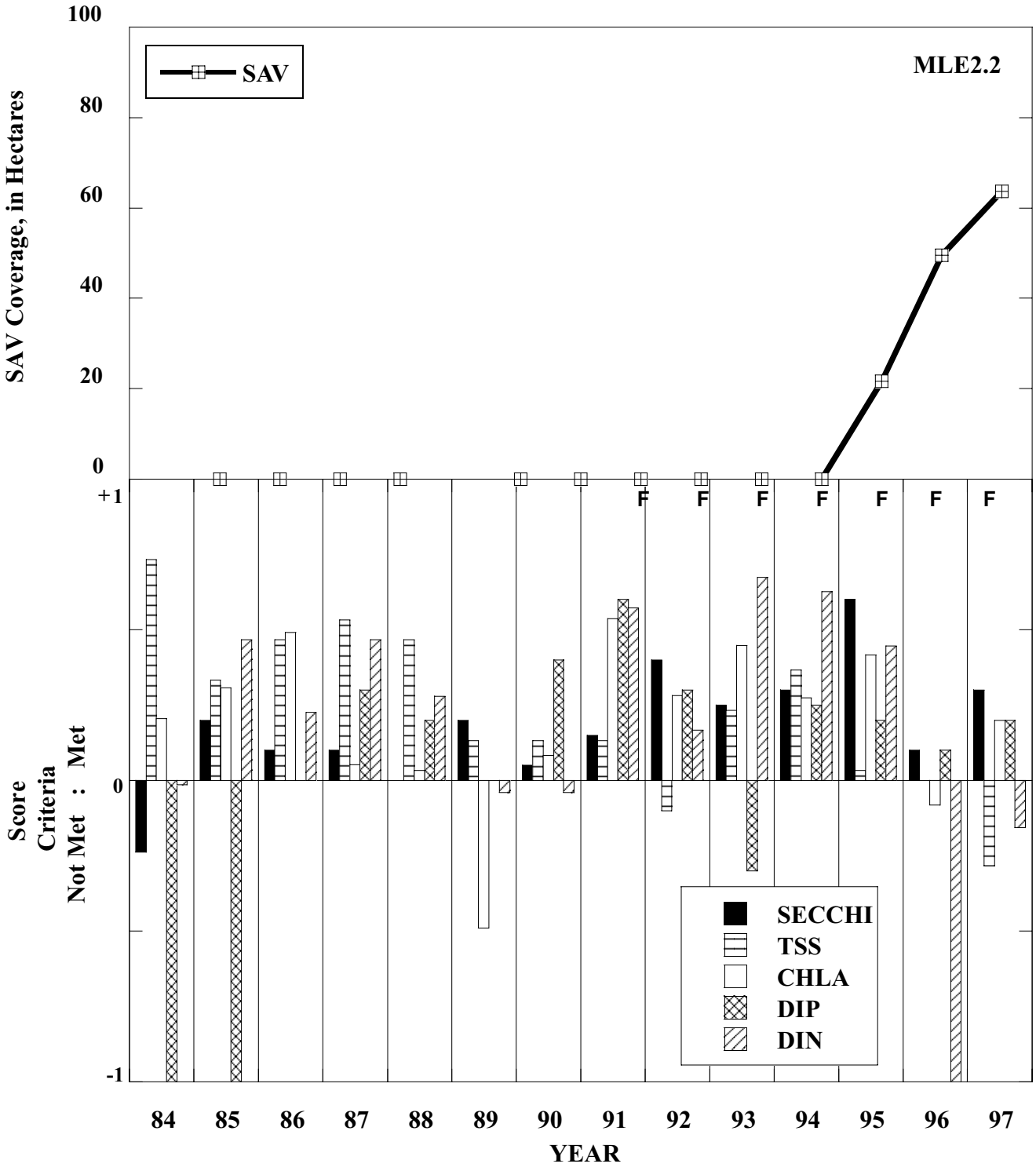

Figure 14. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores for mesohaline Potomac Estuary monitoring station MLE2.2 segment for the period 1983 through 1997. (F denotes use of filtered water samples for DIN and DIP.)

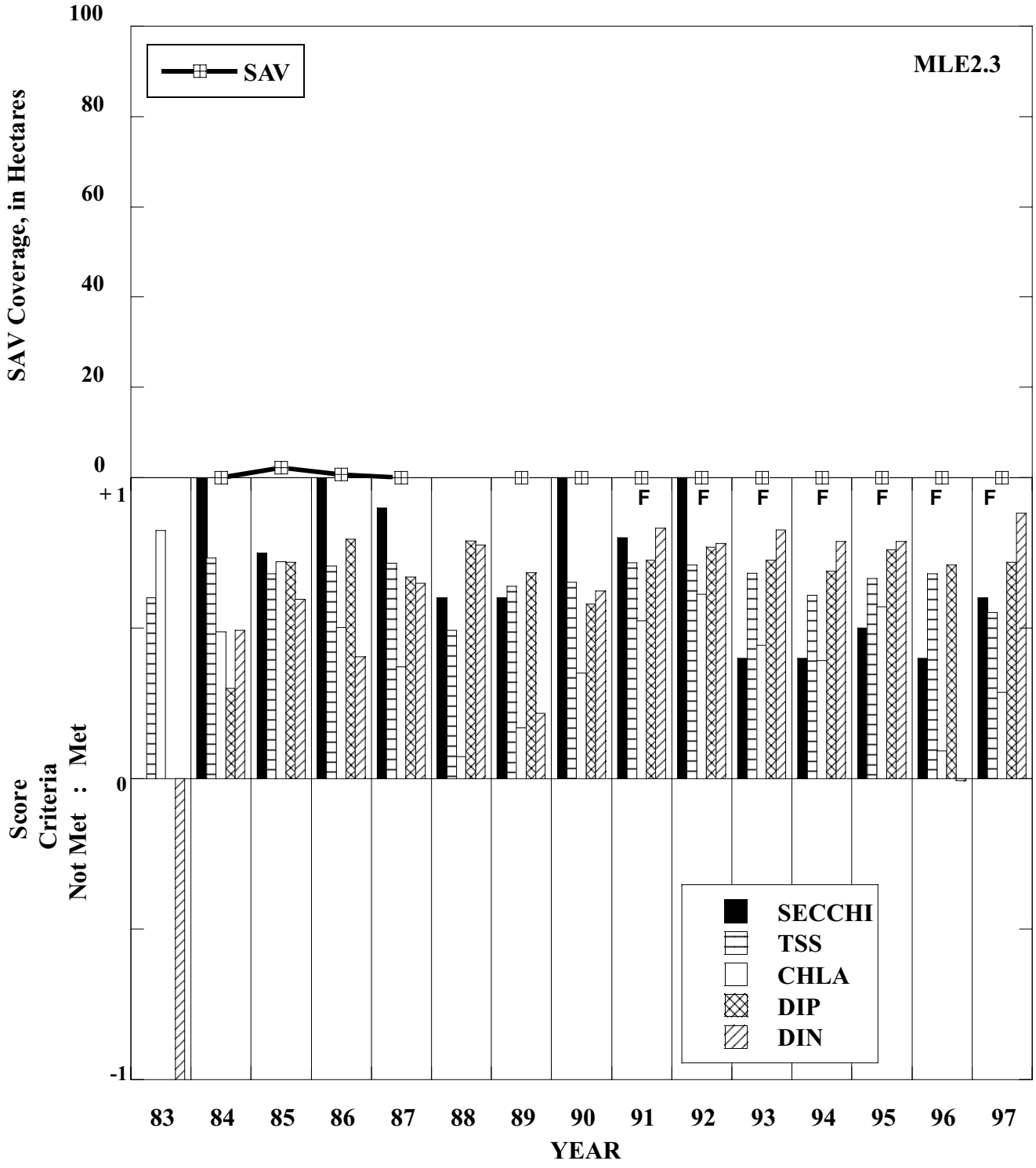

Figure 15. Surface area, in hectares, covered by submersed aquatic vegetation and Chesapeake Bay habitat criteria scores for mesohaline Potomac Estuary monitoring station MLE2.3 segment for the period 1983 through 1997. (F denotes use of filtered water samples for DIN and DIP.)